Exercise: Understanding Positional Astronomy

Part 1 – The Celestial Sphere

Difficulty: Intermediate

Objective

To help learn your way around the night sky it is useful to have some understanding of positional astronomy. Positional astronomy is used to determine the location of celestial objects in the night sky as seen from Earth at any particular date, time and location. It is one of the oldest disciplines in astronomy – the earliest astronomers could not study the composition of stars and planets so their astronomy was limited to documenting, understanding and trying to interpret the movement of celestial bodies. Positional astronomy had a very important part to play in early society: it was used to determine or predict many important events such as religious festivals or when to expect the Nile floods. Astrology was still hugely important and therefore so was the ability to predict the positions of celestial bodies. Positional astronomy also provided an essential means of navigation.

We have split the Positional Astronomy materials into two parts. Part 1 (this part) covers some of the basic concepts and in Part 2 you will learn about how astronomers describe the positions of celestial bodies.

Equipment

To complete the exercises below you will need:

- A protractor
- A piece of string (about 1 metre in length)
- Something small and heavy to use as a weight (such as a fishing weight, a large nut and bolt or a heavy washer)
- A star map

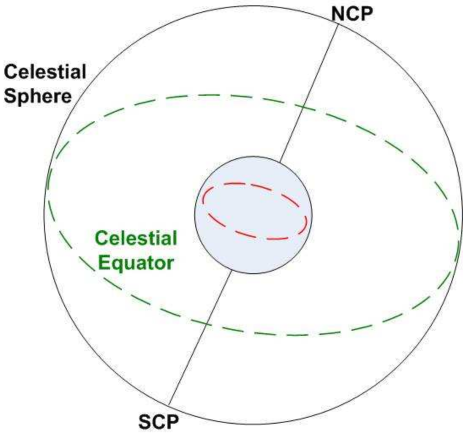
Key Concepts

The Celestial Sphere

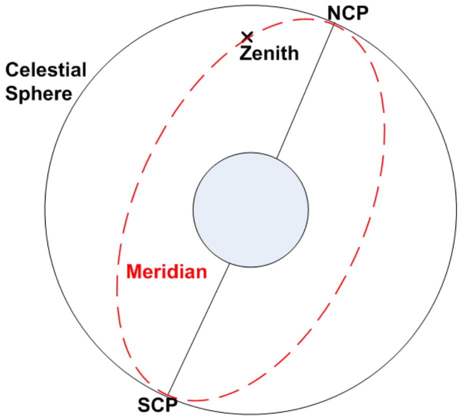
To help our understanding of positional astronomy we imagine the celestial bodies that we see in the sky (the sun, moon, stars, planets, etc.) as if they were fixed to a huge imaginary sphere with the earth at its centre. As the earth rotates on its axis from West to East, the stars appear to move across the sky from East to West. The stars rise in the East, reaching their highest altitude when they are due South and then set in the West. This apparent rotation of the celestial sphere is actually the result of the Earth rotating on its own axis.

Any circle that lies in a plane which divides the Earth into two equal halves is called a *great circle* and its centre must coincide with the centre of the earth (i.e. it must be co-centric). For example, lines of longitude represent great circles, the equator represents a great circle, but lines of latitude do not.

The *celestial equator* is a great circle on the imaginary celestial sphere, in the same plane as the Earth's equator – it can be thought of as a projection of the Earth's equator onto the celestial sphere and divides the celestial sphere into a Northern and Southern hemisphere. Just as the Earth has two poles, the celestial sphere has a corresponding *North Celestial Pole* (NCP) and a *South Celestial Pole* (SCP). If you imagine extending the Earth's axis beyond the North and South poles, it would touch the celestial sphere at the Celestial Poles.



The point on the celestial sphere directly above you is called the *Zenith*. Now imagine a great circle passing through the two poles of the celestial sphere and the Zenith. This circle, projected onto the Celestial Sphere is called the *Meridian* – the location of the Zenith and Meridian is, of course, dependent on your observing location. By definition, your Meridian must pass through the due North and due South points on your horizon.



Whether or not a celestial body is visible depends on the position of the Earth in its orbit around the Sun. At certain times of the year stars and constellations will be above the horizon during daylight and so will not be visible in the bright sunlight. The Constellation of Orion for example is a winter constellation because it is only above the horizon after sunset during the winter months.

Circumpolar Objects

There is a special group of celestial bodies which are sufficiently close to the Celestial Poles that they never set below the horizon – these objects are called ‘*circumpolar’*.

Which celestial bodies are circumpolar depends on your location on the Earth’s surface. For example, if you are observing the sky from London (assuming you can find somewhere dark enough to actually see stars) then Ursa Major is a circumpolar constellation and never sets below the horizon. If you are observing from a location on the Earth’s equator then Ursa Major is not circumpolar, it will rise and set.

You have to be careful when you talk about the horizon. There is the visible horizon is defined by the local geography of your observing site and the astronomical horizon is great circle at right in a plane that sits exactly at right angles to the direction of the zenith.

The Ecliptic

Throughout the course of a year the Sun follows an apparent path in the sky which, when projected onto the Celestial Sphere, maps out a great circle. This great circle is called the *Ecliptic* and it lays at an angle of about 23.5 degrees to the Celestial Equator.

The line of the ecliptic follows the approximate centre of a region of the celestial sphere called the *‘Zodiac’.* The constellations along this region correspond to the twelve signs of the zodiac which are of great importance to astrologers.

Because the orbits of the planets in our solar system all lay roughly in the same plane, the movement of the planets across the Celestial sphere also follows the Ecliptic. Of the other eight planets (remember, Pluto is not a planet any longer) the orbital plane of Mercury has the greatest difference to Earth's at an orbital inclination of 7°.

The Equinoxes

Since the Ecliptic lays at an angle of about 23.5 degrees to the Celestial Equator then twice a year the Sun (following the Ecliptic) crosses the Celestial Equator. On these two dates day and night are of nearly equal length at all latitudes and so we call these dates the "*equinoxes*". Equinox meaning "equal night".

The Equinox in March is called the vernal Equinox and the Equinox in October is the *Autumnal Equinox*. *The Vernal Equinox* is particularly important in positional astronomy as you will see in Part 2.

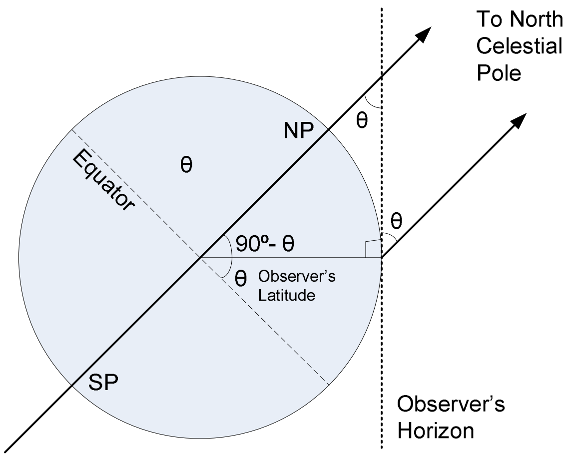
Note that the times when the sun is at its furthest from the Celestial Equator (in mid-winter and mid-summer) are called the *Solstices*.

Exercises

Find your latitude using the Pole Star

Latitude defines the location of any location on the Earth as an angular measurement in degrees north or south of the equator. Lines of latitude are the imaginary horizontal lines shown running east-to-west ranging from 0° at the equator to 90° at the poles.

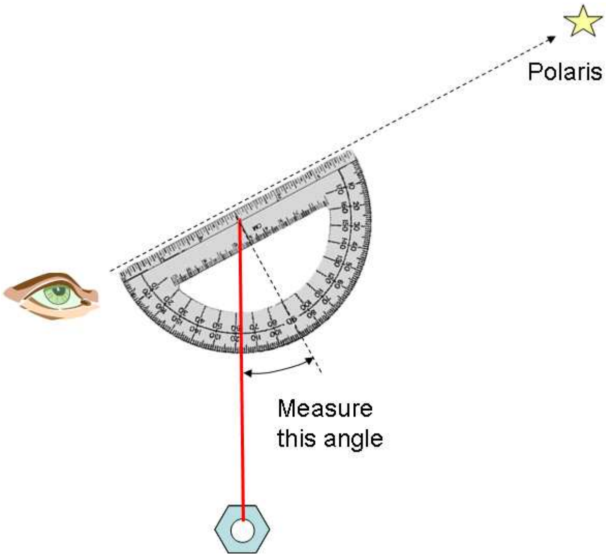
If you live in the Northern hemisphere, you can use the North Star (Polaris) to find the latitude of your observing location because it is the same as the altitude of Polaris. If you want to understand why, look at the diagram below and remember that Polaris appears to sit approximately at the North Celestial Pole.



If you are at latitude θ then the angle between the Earth's axis and a line from the centre of the earth to your location is 90º - θ. The angle between your horizon and the axis of the Earth must also be θ (because the angles in a triangle must add up to 180 degrees). Because your line of sight to the North Celestial Pole is approximately parallel to the Earth's axis (Polaris is a long way away) simple geometry tells us that the angle between the horizon and the line of sight to Polaris must also be θ. It's as simple a that!

A simple way to measure the altitude of Polaris is to use a protractor, the larger the better:

- Make a small hole in your protractor at its centre and push a long length of string through this hole.
- Make a large knot at one end of the string and pull it tight against the hole. Make sure that it is secure and won't pull through
- Tie a small weight to the other end of the string – such as a nut and bolt or a heavy washer.
- Look at Polaris along the straight edge of the upturned protractor keeping its entire edge aligned with the star. Get a friend to read off the angle between the 90º mark on the protractor and the piece of string (see below).



The longer you can make the string the better as it tends to minimise errors due to the weight not being centred on the string.

Lookup your latitude on the Internet (you can find this by entering your postcode on www. streetmap.co.uk) or using a sat-nave or a mobile phone with GPS. How does your result compare? How do you account for any difference?

Keep this simple piece of equipment – you will need it again in Part 2.

Exercise 2 - Find your latitude using a star at your Zenith

There is another way to determine your latitude. When a star is at your Zenith then the declination of that star is equal to your latitude. If you want to try this method:

- Find an easily identifiable star that is directly overhead (i.e. at your Zenith). You might have to wait a little for a star to be exactly at your Zenith!.

- Find this star on a star chart and try to read off its declination (note that not all star chats provide this information but most good ones such as a Philips Sky Chart will provide a scale from which RA and Declination can be read off).

Does the declination of the star match your latitude? How does this compare with the previous method and how do you account for any difference?

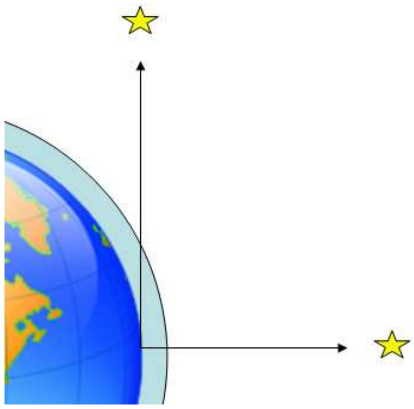
- Identify the name of the star - e.g. γ (gamma) Draconis - and look up its declination on the internet – do you think you judged your Zenith accurately?

Exercise 3 – Circumpolar Stars

Using your the latitude which you have just estimated in Exercise 1, look on your star map and try to determine which stars and constellations are circumpolar. Here is a clue. Think about what happens if a star's distance from the celestial pole is less than, equal to and greater than your latitude.

Identify a circumpolar star that will just skirt the horizon at a convenient time. Try to observe this star as it gets near to the horizon. Is it still visible? You might encounter some difficulties, one being that the astronomical horizon might be obscured from view by buildings and local geography. Try to pick a star that will appear where you have the best view of the horizon to make your comparison more accurate.

Notice that fewer stars are visible near to the horizon. This is due to the combined effects of light pollution, water vapour and dust scattering the starlight. As you look closer towards the horizon you are looking through a greater volume of atmosphere than at the zenith.



Try to see how many stars you can see close to the horizon. Using your star chart, compare their magnitudes with the magnitudes of stars overhead.